DOCUMENT RESUME

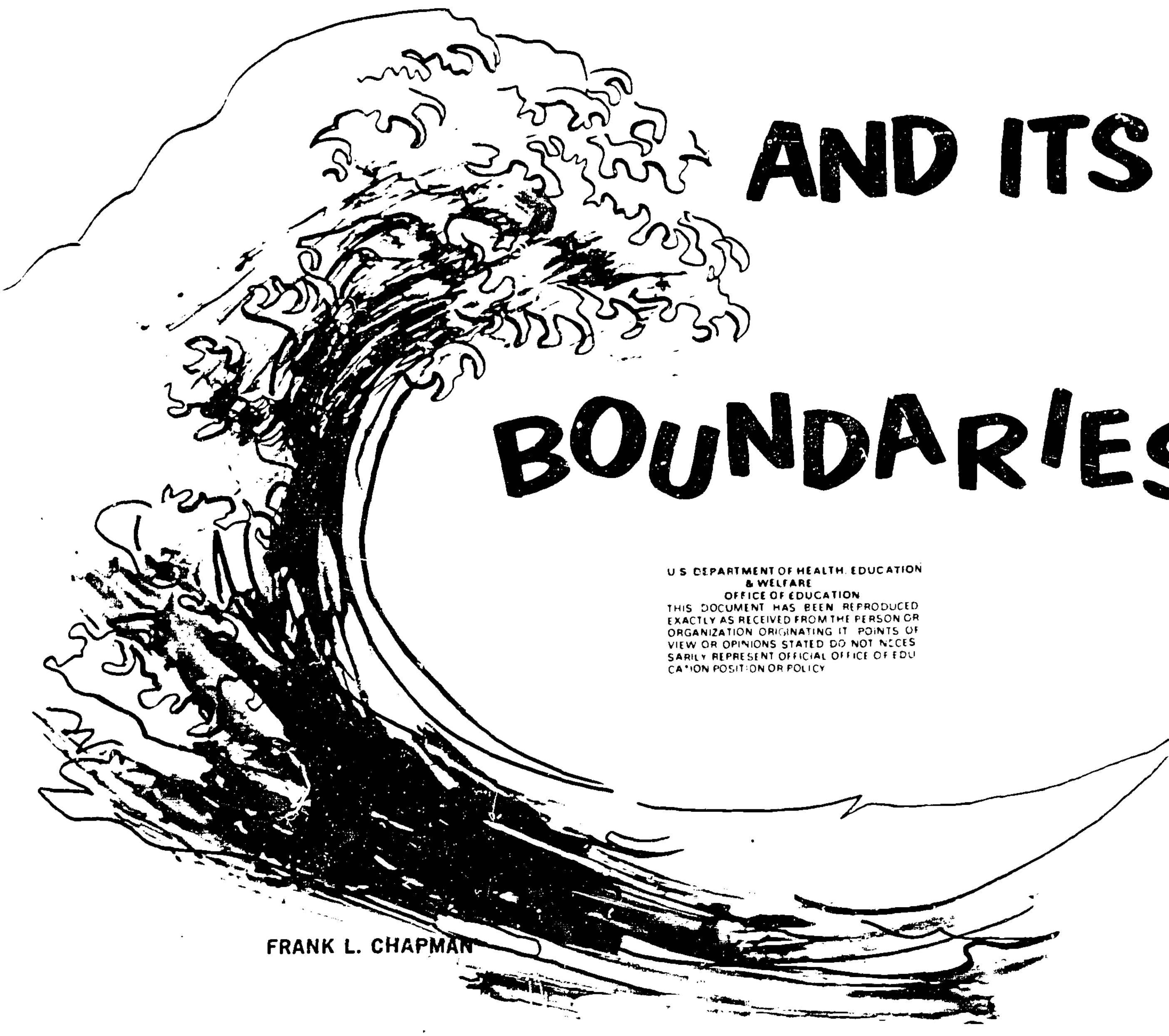
ED 046 735 | SE 010 519

AUTHOR	Chapman, Frank L.
TITLE	The Sea and Its Boundaries.
INSTITUTION	Carteret County Public Schools, Beaufort, N.C.
SPONS AGENCY	Bureau of Elementary and Secondary Education (DHEW/OE), Washington, D.C.
PUB DATE	[70]
NOTE	31p.
AVAILABLE FROM	Regional Marine Science Project, Carteret County Public Schools, Beaufort, N.C. 28516 (Free)
EDRS PRICE	EDRS Price MF-$0.65 HC Not Available from EDRS.
DESCRIPTORS	Curriculum Guides, Earth Science, *Ecology, *Elementary School Science, Environmental Education, *Instructional Materials, Natural Resources, *Oceanology, *Textbooks
IDENTIFIERS	ESEA Title III

ABSTRACT

This publication is designed for use as part of a curriculum series developed by the Regional Marine Science Project. As an informative text for a three-week unit in marine science for grade eight, it presents a study of coastal processes and oceanography. An ecological approach to nature is emphasized, stressing the ties between culture, economy, and resource use. Topics are divided into three units: Physical Oceanology covers tides: The Sea at Its Boundary discusses waves, beaches, and man's control of the beach environment; and Beyond the Land describes the off-coast profile, elements in the water, winds, currents, and sea testing equipment. Each unit includes a vocabulary, fill-in questions, discussion topics, and activities to complete. Numerous diagrams illustrate topics discussed. This work was prepared under an ESEA Title III contract. (BL)

THE SEA AND ITS BOUNDARIES



FRANK L. CHAPMAN

CARTERET REGIONAL
MARINE SCIENCE PROJECT

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THE SEA AND ITS BOUNDARIES

by FRANK L. CHAPMAN
illustrated by WILL HON

This publication is designed for use as part of a curriculum series developed by the Regional Marine Science Project of the Carteret County Public Schools, financed primarily by ESEA TITLE III. The series will include three-week teaching units in marine science for grades 4-10 and two full-year high school courses in advanced biology.

All materials take an ecological approach to nature, stressing the ties between culture, economy and resource use. Field work is an integral part of the curriculum.

Publications are distributed at cost to interested school systems. Most are designed for wide spread use on the central eastern seaboard. Address inquiries to:

Will Hon
Project director,
and series editor.

PHYSICAL OCEANOLOGY

Leonard Engel was right when he said that our planet has the wrong name. Since there is three times as much water as land on the surface of our planet, why not call it "Ocean" instead of "Earth." It seems strange that in spite of all this water, man has only recently begun the systematic study of the oceans. Scientists call this study OCEANOLOGY. Oceanology is the study of all things about the ocean. Oceanology includes geology, chemistry, physics, biology and other sciences.

Most oceanologists recognize four major bodies of water which they call oceans. The Pacific is the largest, the Atlantic second in size, the Indian third, and the Arctic the smallest. Some oceanologists recognize a fifth ocean, the Antarctic, but this depends on their definition of an ocean. Most oceanologists agree that an ocean should be bounded by continents, distinctive bottom features, or other physical factors. Although these oceans have different names, we should keep in mind that they are interconnected and water can pass from one into the other.

Scientists once thought that all ocean floors were smooth plains with no hills or mountains on the bottom. However, modern methods of depth finding show that the ocean floor is very rough. There are hills, mountains, and valleys much like those found on the land. In many cases, these ocean mountains are much larger than those on land.

Man has always been familiar with the ways the ocean can change a coastline. Often, he has attempted to keep these changes from taking place. His attempts usually fail and more damage results.

These are just a few of the problems the modern oceanologist must deal with. In order for us to study the ocean and some of its effects, let's start at the edge of the land where the ocean is more familiar to us.

TIDES

One of the things an "inlander" would see on a visit to the coast is the rhythmic variation in the depth of the water at different times of the day. Coastal people would recognize this variation as the result of the TIDE.

The importance of tides to people living on the coast is great. Those who make a living from the sea are influenced in their fishing and shipping by the deep or shallow water resulting from the tides. Other coastal dwellers must keep a wary eye on storms. Storm winds can raise the level of the tide to great heights. Finally, and certainly not least, many marine animals and plants (including commercially important species) are influenced by the tides.

Man has been observing the results of the tide since he took to the sea. Yet, it is only recently that he has been able to explain the tides. Ancient mariners thought the tide was caused by the breathing of the earth monster. Later in history, when man began recording the events around him, he found the tides to be closely related to the movements of the moon.

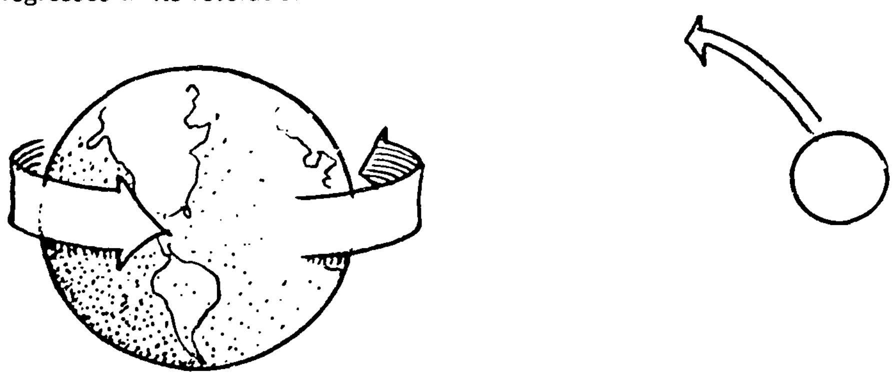
He found that every twenty-four hours and about fifty minutes a complete tidal cycle of two highs (floods) and two lows (ebbs) are completed. Modern science has confirmed that lunar cycles, along with solar and other cycles. do influence the tides.

Although the sun is much larger than the moon, the moon's pull is greater. This is because the moon is so much closer to the earth than the sun. Other celestial bodies also exert a gravitational pull on the waters of the earth, but not very much.

How do the oceans on earth react to the pull of the moon and the sun? The gravitational pull of the moon causes a bulge of water toward itself and on the opposite side of the earth. It is as if the water directly under the moon were being pulled away from the earth, while the earth was being pulled away from the water on the other side. Actually it is more complicated and involves mathematical calculations of the moon's gravity and centrifugal forces on earth.

The moon's gravity causes two bulges of water on the earth's surface. One toward the moon and one on the opposite side of the earth.

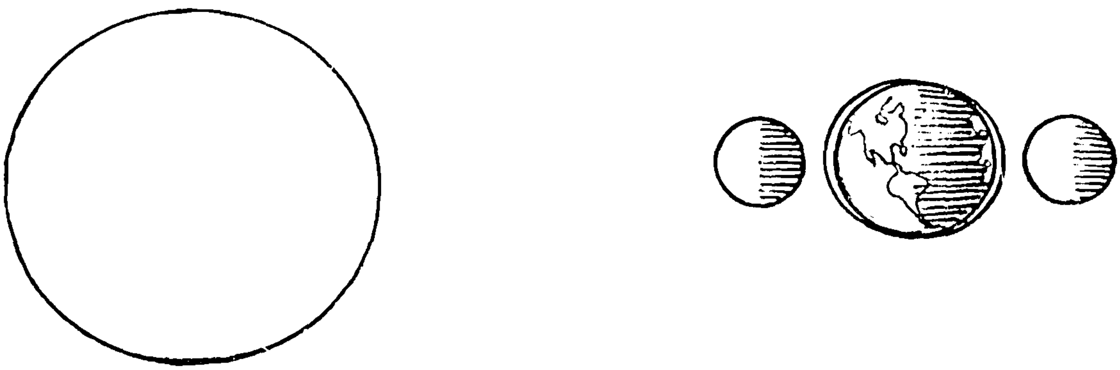
Since the moon travels around the earth once every month, we should have one low and one high tide each month. However, the earth rotates once every twenty-four hours. This results in the daily high and low tides. But, if the earth rotates every twenty-four hours, why does the tide average twenty-four hours and fifty minutes? This is because the moon is revolving around the earth in the same direction that the earth is rotating. It takes an average of fifty more minutes for a spot on the earth to pass under the moon each day because the moon progresses in its revolution.



If the moon remained in the same position with the earth at all times, North Carolina would pass under the moon every 24 hours. But, the moon revolves around the earth in the same direction that the earth rotates. While North Carolina makes a complete circle in 24 hours, the moon has traveled about 54,636 miles ahead. In order for North Carolina to pass directly under the moon again, it must travel for about another 50 minutes. Thus, the tides are about 50 minutes later each day.

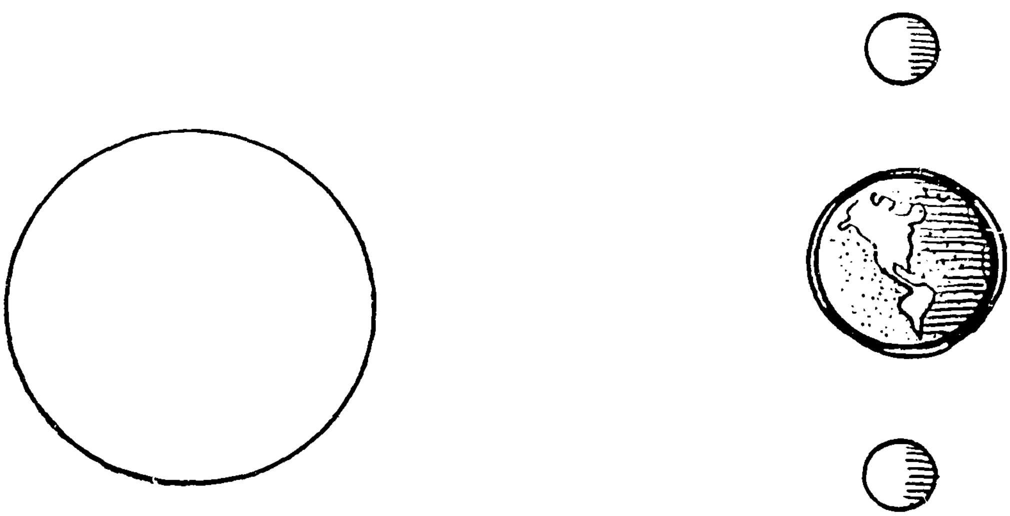
The sun presents some influence on the waters of the earth. The smaller sun bulges are usually out of phase with the moon bulges and do not overlap them. However, two times a month the bulges are in phase and this produces SPRING TIDES. Spring tides occur at the time of the "new moon" (sun and moon lined up on the same side of the earth) and the "full moon" (sun and moon on opposite sides of the earth).

Spring tides represent the highest and lowest of the tides. New moons produce higher water than full moons. Why? Because the sun and moon are pulling in the same direction.



When the moon, sun, and earth line up at full and new moon, the tides are highest and lowest. The tides at that time are called spring tides.

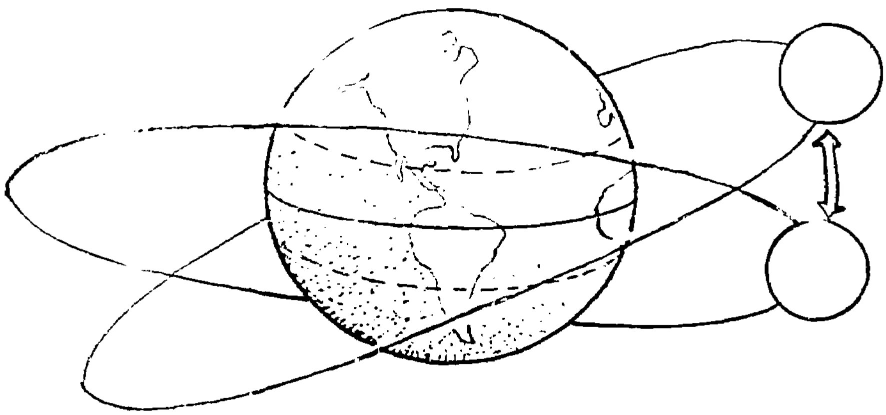
Another and almost opposite effect is achieved when the moon is at first and last quarter. This produces the least high and low tides, which are called the NEAP TIDES. In this phase the moon, earth, and sun form a 90 degree angle and the bulges are out of phase.



Neap tides occur when the moon, earth, and sun form a 90° angle with each other. The tides do not change as much from low to high at this time.

The change from spring tide to neap tide is gradual, following the progressive movement of the moon around the earth.

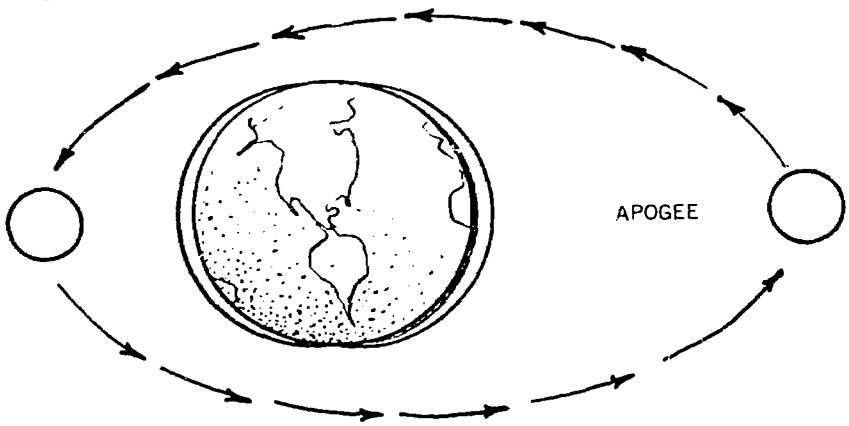
Besides spring and neap tides, there are other reasons why the tides are not equally high or low. The moon and sun are not always directly over the equator, but vary north or south. The moon varies as much as 28 degrees north or south each month. However, two times in the 30 day period the moon will be directly over the equator.



The Moon changes positions in relation to the earth each month. Since the tidal bulges follow the gravity of the moon. They will also change with the moon.

Likewise, the sun is over the Tropic of Cancer (23½ degrees north) and the Tropic of Capricorn (23½ degrees south) once each year and over the equator two times a year. As the sun and moon vary from northern to southern hemispheres and back again, the tidal bulges follow their movement.

The orbit of the moon around the earth is not round. Rather, it is eliptical with a distant point (apogee) and a near point (perigee). The same is true for the orbit of the earth around the sun. Since gravity exerts the strongest influence on objects when they are nearest, perigee tides will be greater.



Perigee tides will be more extreme than apogee tides because the moon is closer at perigee.

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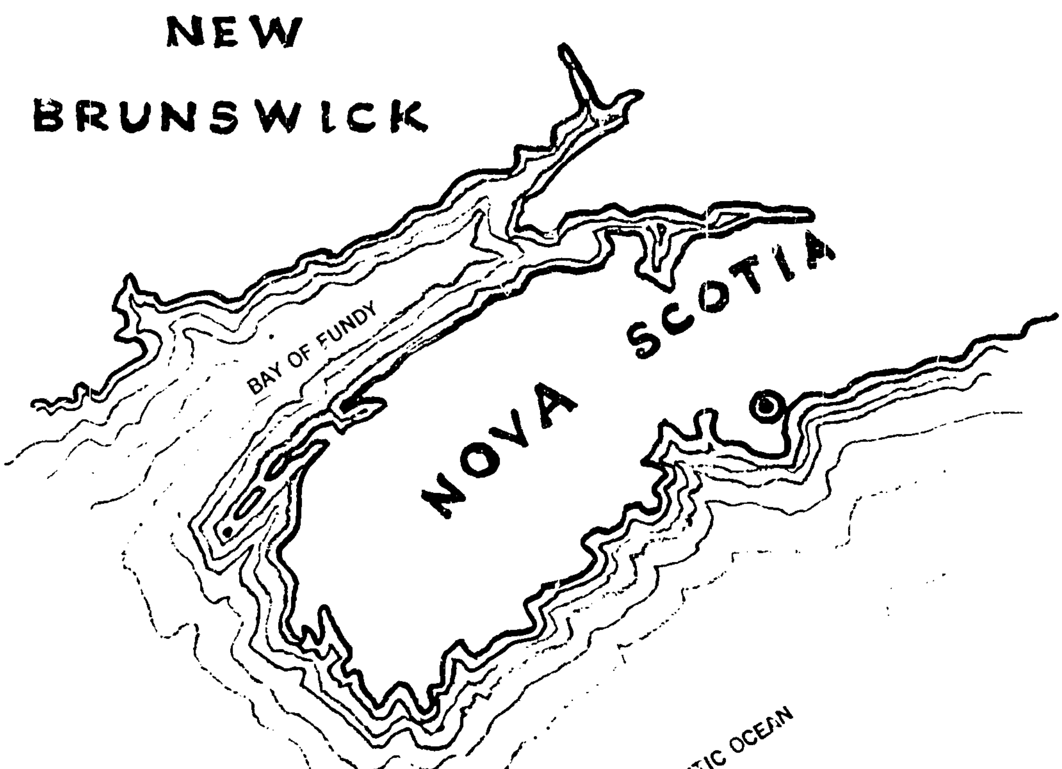
Winds also produce variation in the tides. If a strong wind is blowing with a flooding tide, the water may be several feet higher than predicted. Likewise, if a wind is blowing in the opposite direction to the ebbing tide, the water may remain higher than at normal ebb tide. This caused by friction of the air against the water. Witness the extreme tides of hurricanes. when water is actually blown in or out according to the direction of the wind.

The topography of the bottom of a body of water exerts a tremendous influence on the results of the tide. The Bay of Fundy, with fifty feet of variation at its head, is an excellent example. Fundy is deep and wide at its mouth and gradually gets shallow and narrow toward the head. At low water the upper reaches of the Bay are dry. As the tide changes, large volumes of water entering the deep mouth find only limited space to fill as it proceeds toward the head of the Bay. Consequently the large volume of water is pushed upward by the rising bottom. At high tide (flood) the water level reaches as much as fifty feet and the tidal currents run as fast as eight knots. This makes it very dangerous for fishermen caught in the basin on changing tides.

In contrast to the Bay of Fundy are the tides at Halifax, Nova Scotia. Halifax is located on Atlantic and the water is rather deep near shore. Tides here range at the most only seven feet. Also associated with bottom topography and flooding tides, are TIDAL BORES. A tidal bore is a wave of water created by the flooding tide as it moves up a coastal river. They are caused by an incoming tide.



Map of New Brunswick and Nova Scotia showing the Bay of Fundy as it narrows and shallows at the Minas Basin and Petitcodiac River.

As the tide moves in the river, it is held back by friction with the bottom and the water flowing out of the river. When it reaches a certain height the force of the water overcomes the force against it. The tide then moves up the river as a translation wave, that transports water from one place to another. The tidal bore of the Petitcodiac River (off the Bay of Fundy) ranges as high as five feet. The exact height depends on the phase of the moon. The bore of the Tsientang River of China is said to reach a height of twenty-five feet and all shipping is controlled by the bore.

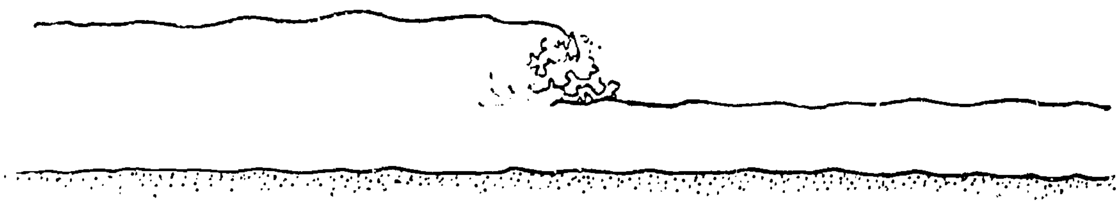
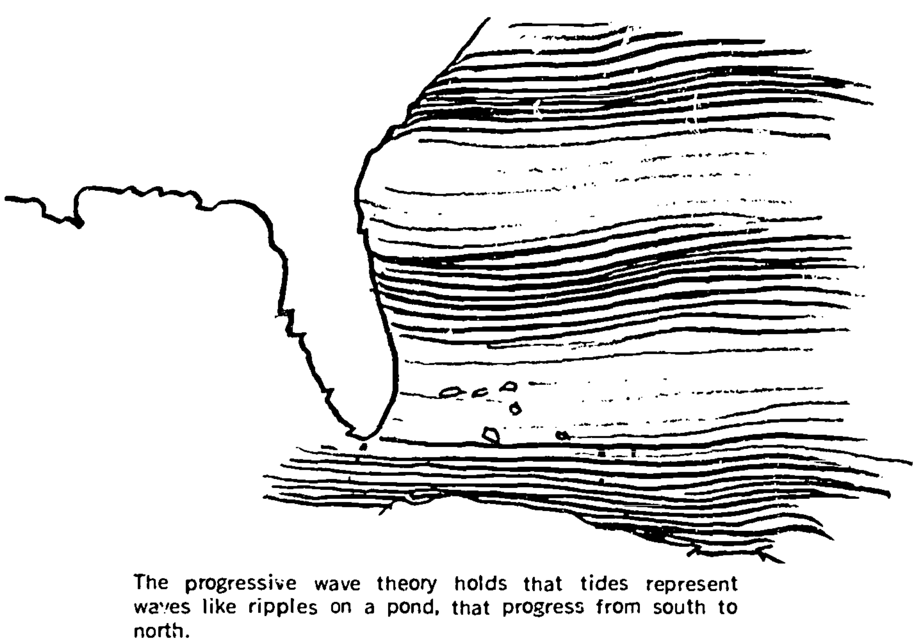


Diagram of tidal bore moving up a river. Note that water remains high after the bore front passes.

The coast of North Carolina experiences two flood and two ebb tides each 24 hours and 50 minutes. This is called a SEMI-DUIRNAL TIDE. Another cycle found in the United States on areas of the Gulf of Mexico Coast is the DIURNAL TIDE. The diurnal tide consists of one high and one low each 24 hours and fifty minutes.

The tides of the Society Islands in the Pacific show an unusual situation. The tide is high at approximately 12 o'clock noon and 12 o'clock midnight every day. Their tides are evidently responding to the sun's pull. How can we explain this solar-produced tide, when we know that the moon exerts much more influence on the earth's waters than does the sun?

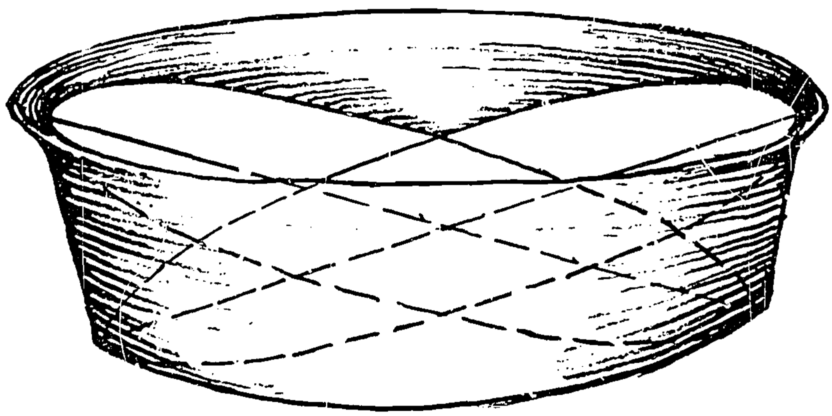
Two theories have been formulated to account for unusual solutions such as this. The PROGRESSIVE WAVE THEORY holds that tides are the results of waves, like ripples in a pond.



The progressive wave theory holds that tides represent waves like ripples on a pond, that progress from south to north.

On the Atlantic Coast of the United States these waves appear to move from south to north, with high tides generally progressing later to the north. In the Society Islands, two such waves moving from different directions would have to meet at the island two times per day to result in the tidal cycles present there. There are some errors in this theory and scientists now think that the stationery or standing wave theory may be the most important.

The STANDING WAVE THEORY is based on the fact that every body of water oscillates naturally. If water in a dishpan is made to slosh back and forth (oscillate), we will see that it almost goes over one side, while it is almost gone from the other side. This continues back and forth. The water will shift back and forth very rapidly in our dishpan but more slowly in a large container. While the water is sloshing back and forth, we can see a spot in the middle of the dishpan where there is no up or down movement of the water. This point is called the NODE. Our dishpan was a "basin" for the water, and the ocean has many such basins formed by the topography of the bottom. Each of these has its own PERIOD OF OSCILLATION (time to complete a cycle from one side to the other and back again). Little force is needed to keep this oscillation in motion, and the force of the moon and sun is sufficient for natural basins on earth.



The standing wave theory states that natural basins of water slosh back and forth. At the center of this slosh there will be no movement of water (node), but at both ends the tides will rise up and down.

The Society Islands may be located in the node of a moon—influenced oscillating basin. At least, tides in areas around the Society Islands fluctuate with movements of the moon. Since the moon would cause little movement at the Society Islands (node) the sun would be free to influence tides here. Indeed, this seems to be the case.

Like most natural phenomena now studied, tides are complicated. They are the results of many combined factors and not alike in any two places. One tidal theory may explain the tides at one place, but not another. So we must use both theories to explain tides all over the world.

As tides are regular in their movements, they can be predicted far in advance. The Coast and Geodetic Survey of the United States Department of Commerce has published daily tide tables for the Atlantic Coast since 1867. These can be purchased from the United States Government Printing Office in Washington, D. C., and in local nautical shops.

It would be impossible for the tide tables to cover every spot along the Atlantic Coast. However, they do cover the most important areas for shipping. If you desire to know the tides for an area between two reported spots, you would have to estimate according to the distance between the two reported spots. This is called INTERPOLATION. For instance, if hightide occurs at 0200 hours at spot A and 0400 hours at spot C, Spot B, half-way between spot A and C, would have high tide at 0300 hours.

Some areas are covered by a full report. Hampton Roads, Virginia, is one of these. Other areas can be calculated by adding or subtracting a particular time factor from one of the complete charts. For instance, Cape Lookout and Shell Point on Harkers Island are calculated from Hampton Roads, Virginia. In order to determine the time of high water at Cape Lookout you must subtract two hours and eight minutes from the Hampton Roads tide table. For low water we must subtract two hours and eighteen minutes from the Hampton Roads tide table (see sample chart).

HAMPTON ROADS (SEWELLS PT.), VA., 1968
TIMES AND HEIGHTS OF HIGH AND LOW WATERS
OCTOBER

Day	Time	Ht.	Day	Time	Ht.
	H.M.	Ft.		H.M.	Ft.
16	0406	2.1	20	0112	0.0
W	1006	0.7	SU	0730	3.1
	1630	2.5		1348	0.0
	2254	0.5		1954	2.8
17			21	0154	0.1
TH	0506	2.3	M	0818	3.3
	1106	0.5		1436	0.2
	1725	2.6			2.9
	2348	0.4			
			22	0242	−0.2
18	0554	2.6	TU	0900	3.4
F	1206	0.3		1524	−0.2
	1818	2.7		2124	2.8
19	0030	0.2	23	0324	−0.3
SA	0642	2.8	W	0948	3.5
	1300	0.1		1612	−0.2
	1906	2.8		2212	2.7

No.	Place	Position		Differences			
		Lat.	Long.	High Water	Low Water	High Water	Low Water
	North Carolina's Outer Coast	o' N.	o'	h.m.	h.m.	feet	feet
				On Hampton Roads, Time meridian, 75° W.			
2461	Cape Lookout	34 37	76 32	−2 08	−2 18	+1 2	0.0
2463	Shell Point, Harkers Island	34 41	76 32	+0 08	+0 40	−1.2	0.0
2465	Beaufort	34 43	76 40	−1 00	−0 51	−0.0	0.0

Included with the time of high and low water is the expected height of the tides. It must be remembered that the tides are influenced by many factors and these predictions are for ideal conditions. Referring to charts, find the time and heights of high and low tides at Cape Lookout on 23 October 1968. By using the chart we can calculate that high tide will occur at 0740 and 2004. Tides are read from the twenty-four hour clock, which starts at midnight and keeps counting hours until the next midnight, twenty-four hours later. This reduces the chance of the A.M. and P.M. error. We must also keep in mind that the tide prediction chart is set up for standard time. This means we must correct for daylight savings time from 1 April to the last Sunday in October.

0948	Hampton Roads high	2212	Hampton Roads high
-0208	Cape Lookout correction	-0208	Cape Lookout correction
0740	Hours	2004	Hours

Calculate for the low tides on 23 October 1968 in the same manner. Be careful to note that the correction factor for high and low is different. Low tides occur at 0106 hours and 1354 hours.

To find the expected height of high water at Cape Lookout from the chart, we must add 1.2 feet to the Hampton Roads high water readings (2.3 feet + 1.2 = 3.5 feet above average sea level). The chart also says that low water at the Cape will be the same as at Hampton Roads.

VOCABULARY

Diurnal Tides: A tidal cycle of one high and one low tide about every 24 hours and 50 minutes.

Ebb Tide: A tide that is falling, receding, going out.

Flood Tide: A tide that is rising, coming in.

Neap Tides: Tides that have the least variation of water level between high and low. Neap tide occurs when the sun, earth and moon form a right (90 degree) angle with each other.

Node: A point in the middle of an oscillating basin that remains stationary.

Progressive Wave Theory: A theory which states that tides are the result of large water waves moving past an area.

Semidiurnal Tides: A tidal cycle of two high and two low tides about every 24 hours and 50 minutes.

Spring Tide: Tides that have the greatest variation of water level. Spring tides occur when the sun, moon, and earth form a straight line.

Standing Wave Theory: A theory which states that tides result from oscillation (sloshing) of water back and forth in a matural basin.

Tidal Bore: A translation wave that travels up a river as the result of a flooding tide.

Tidal Currents: Movements of water from one place to another in response to the tides.

QUESTIONS

Fill in the blanks with the correct answer.

1. On the North Carolina coast there are two high and two low tides each 24 hours and 50 minutes. We call this kind of tide a ____________________ tide.
2. Neap tides occur when the sun, earth, and moon form a ____________________ degree angle with each other.
3. During a ____________________ tide a coastal area will experience its highest and lowest tides. This occurs when the sun, earth and moon form a straight line with each other.
4. If the tide is high at Beaufort, North Carolina at 1200 hours, the next high tide will occur at about ____________________ hours.
5. Two theories that represent an attempt to explain the tides of the world are the ________ ________ ____ and ____________________ wave theories.
6. The ____________________ ____________________ of the Petitcodiac River is a translation wave that passes up the river at high tide.

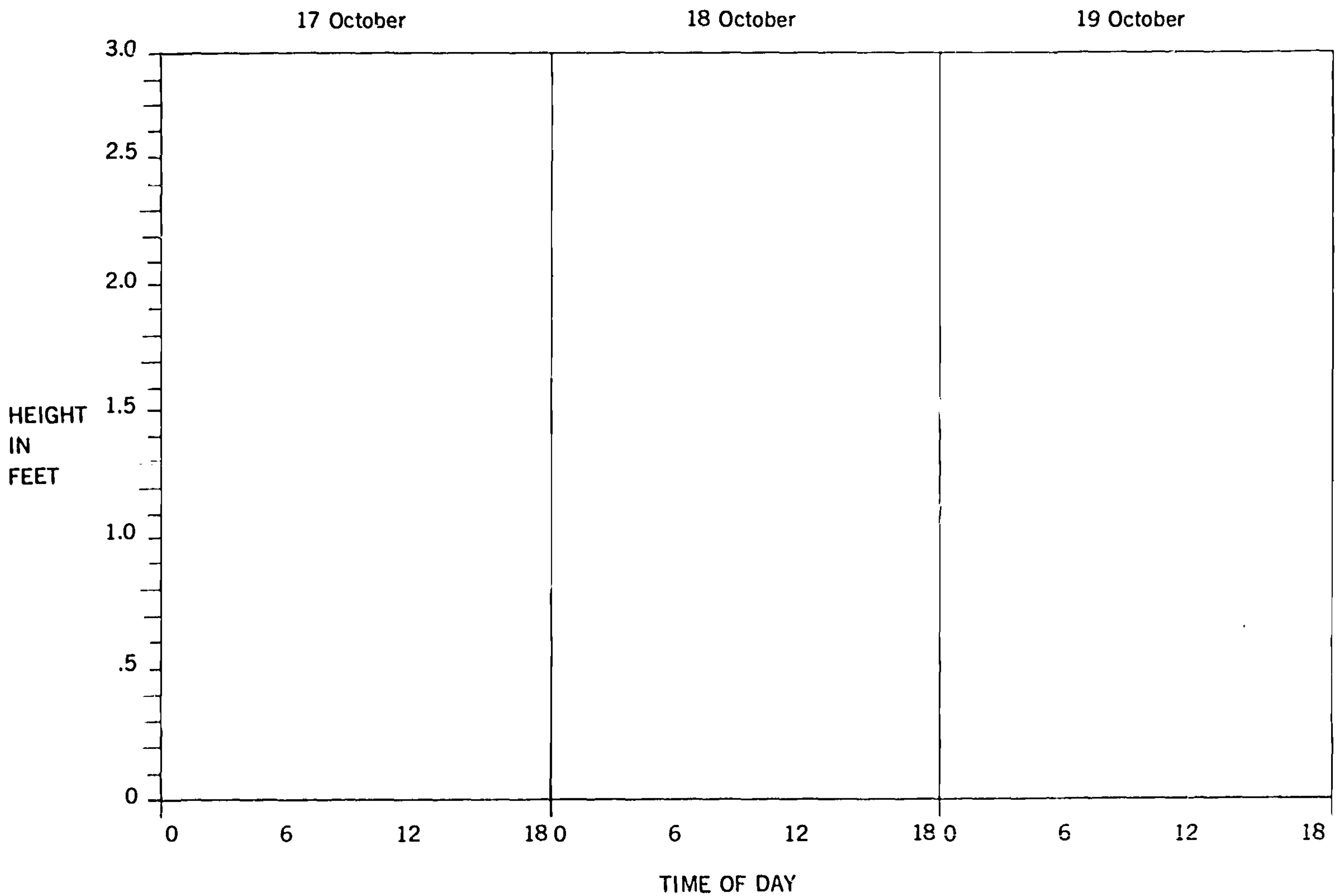
Discuss the following questions.

1. Explain why the tides at Beaufort, North Carolina, differ in height from one time to another.
2. Explain why scientists think the high tides at the Society Islands in the Pacific occur at 12 noon and 12 midnight. Explain how both tide theories can account for this.
3. Explain why the tidal cycle is 24 hours and 50 minutes, when the earth makes a complete rotation in only 24 hours.
4. Design a device for measuring the tides. Explain how it will operate.

ACTIVITIES

All of the problems in this exercise refer to the tide prediction chart in your book. You will also need a ruler and a pencil to answer the questions below.

1. At what time did low tide occur at Hampton Roads, Virginia, on 18 October 1968?
2. When did high tide occur at Hampton Roads on 22 October 1968?
3. What were the times and heights of the high tides on 20 October 1968 at Beaufort, North Carolina? What day of the week is this?
4. What were the times of the two flood tides at Cape Lookout on 16 October 1968? What were the heights of the tides?
5. What is the latitude and longitude of Beaufort, North Carolina?
6. Construct a graph like the one on the following page. Draw a continuous tide curve for Shell Point, Harkers Island, North Carolina, for 17, 18, and 19 October 1968 on the graph you construct.


17 October
18 October
19 October
HEIGHT
IN
FEET
3.0
2.5
2.0
1.5
1.0
.5
0
0
6
12
18 0
6
12
18 0
6
12
18
TIME OF DAY

ACTIVITIES

The progressive wave theory states that the tides are the result of waves, like ripples on a pond, moving from one area to another. High tides are the crests (high part) of the wave and low tides are the troughs (low parts).

The standing wave theory states that tides are the result of water oscillating in a natural basin. High tides are where the water is highest and low tide is where the water is lowest. The water will oscillate back eventually and the situation will be reversed.

Materials:	Water, dishpans of various sizes, watch or clock with a second hand, pencil, and paper.
Object:	To observe on a small scale how the standing and progressive wave theories may operate to produce the tides.
Methods:	STANDING WAVE THEORY—Fill your different sizes of pans about half full of water and allow them to settle. Start the water oscillating by lifting one side of a pan and setting it down. Count the number of seconds for the water to make one complete oscillation (the water to go from high to low and back to high again). Do this for each of the different size pans. The time for one complete oscillation is called the period of oscillation. Make a chart and repeat the operation two or three times.

Questions:
1. What size pan has the fastest period of oscillation?
2. In the center of the pan is a spot where the water does not move up or down. What is this spot called?
3. You started the water oscillating by lifting the pan. What force is responsible for the oscillation of ocean basins?

Methods:	PROGRESSIVE WAVE THEORY—Use the large pan of water. Allow the water to settle down. Slap the water sharply with the end of your pencil. Observe the ripples (waves) produced.

Questions:
1. What force could produce progressive waves in the ocean?
2. How do these differ from standing waves?
3. Can standing waves and progressive waves occur at the same time? See if you can create both kinds in your large pan.

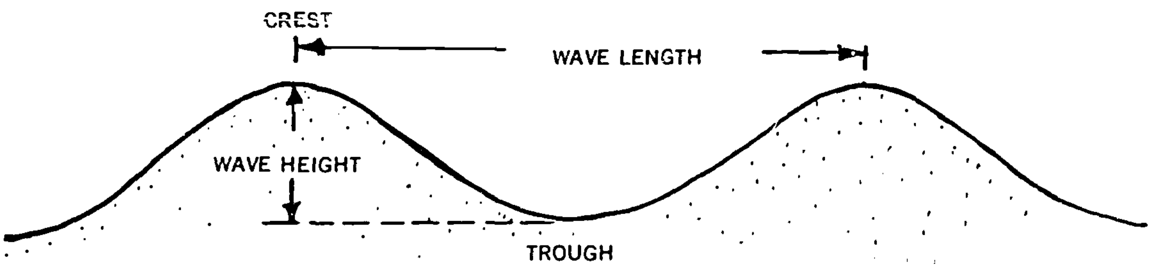
THE SEA AT ITS BOUNDARY

WAVES

If you have ever been surfing, you know that there is more to it than just standing on a board. In fact, the first thing a beginner must learn is how to get out through the surf. The next thing he must learn is to judge when the next wave will get to him so that he can catch a ride. With a little practice at this, he will see that the waves seem to follow each other in a pattern. In fact, they seem to break at about the same spot each time. Each one breaking at this spot will seem to be about the same size. Only after acquiring this bit of knowledge is the surfer ready to concentrate on riding the board.

Most of us may never go surfing, but waves are still important to us. Not only can waves cause serious damage, but they can benefit us when we harness their energy. Let's begin a study of waves by looking at their anatomy.

Waves are made up of the CREST and TROUGH. The crest is the highest part, and the trough is the lowest part. Waves can be measured for length and height. The horizontal distance between wave crests is called the WAVE LENGTH. The vertical distance between the crest and the trough is called the WAVE HEIGHT.



Anatomy of a wave. The time for two successive waves to pass any spot is called the wave period.

Waves are timed by measuring the time it takes for two wave crests to pass a spot. This time is called the WAVE PERIOD.

We know that waves move from place to place as SWELLS. We also know that these same swells will end their journey on some beach as BREAKERS. But, do these waves carry water from one place to another? In order to find this out, scientists build wave tanks. The wave tank is a long rectangular structure with glass sides. Waves are generated at one end and can be observed as they move to the other end. Neutrally buoyant particles are introduced in the tank and their movement observed as swells pass. Interestingly, the particles do not appear to move forward. To see exactly what is happening the observers can trace the movement of the particles on the side of the glass. They find that the particles make a complete circle as a swell passes. This can be observed on a windless day at the ocean when there are swells present. Throw a floating object into the water and watch its movements.

How far below the surface of the water does this circular movement occur? The wave tank again becomes useful as a scientist's tool. Neutrally buoyant particles are placed from the surface of the water to the bottom. When waves pass they disturb the water to a depth of **one-half the wave length.** Below this, there is no disturbance caused by the wave.

When waves encounter water shallower than one-half their wave length, such as at a beach, they are said to "feel bottom." As the water becomes shallower, the circular motion at the bottom is altered. The water there is slowed down. At the surface the circular motion is still

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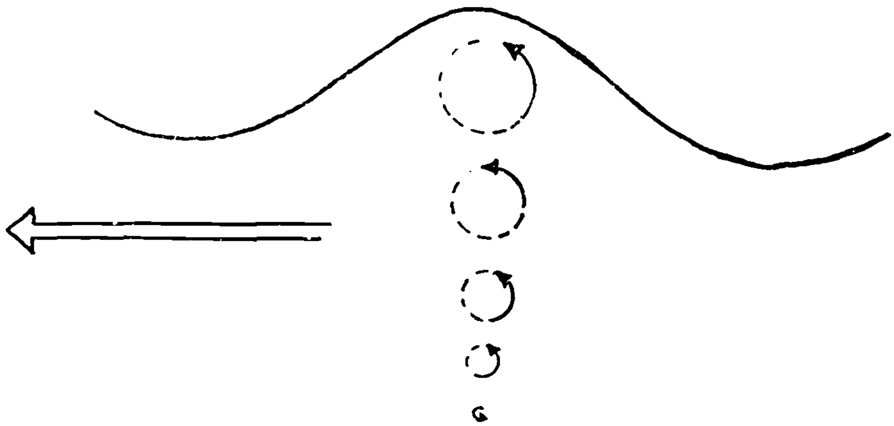
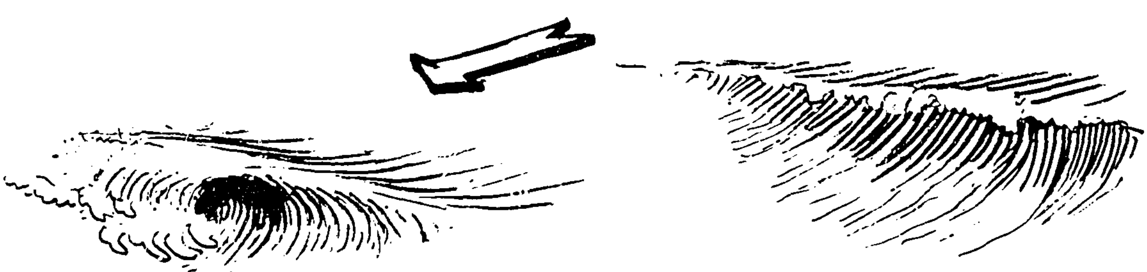


Motion of a particle of water in a wave. Notice the path forms a circle. There is slight movement forward, but not very noticeable. When many waves pass however, a large mass of water is moved very slowly. We call this **mass movement.**

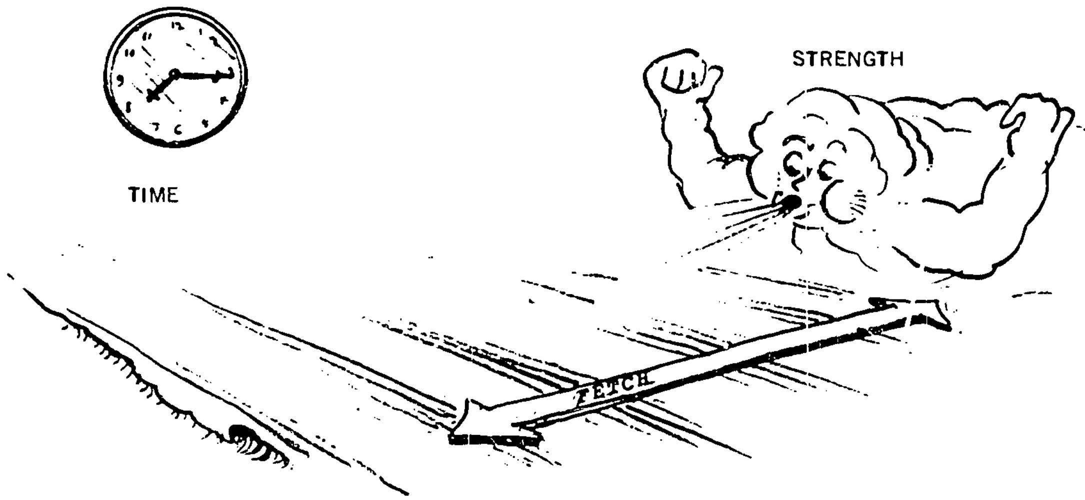
moving very rapidly. In fact, it moves so much faster than the bottom of the wave that the top will spill over in front. Then the wave is known as a BREAKER. Breakers **do** carry water along with them. Waves that transport water are called TRANSLATION WAVES. If the wave breaks very quickly, the crest will be thrown into the trough in front. This leaves, for a short time, a tunnel of water (surfers call this the Banzai Tunnel) and the wave is known as a PLUNGING WAVE. If the process is slow, the crest simply tumbles down the front of the wave into the trough. This kind of breaker is known as a SPILLING WAVE. Surfers prefer spilling waves because they last much longer than plunging waves.



PLUNGING SPILLING

Two types of breakers.

Now we know a little about waves, but what generates them and where do they come from? The waves we commonly see at the seashore are WIND WAVES. These are generated by the friction of wind blowing across water. Usually, wind waves are rather small, but storms can produce large waves. The size of wind waves are dependent on three factors, the **fetch** (distance over which the wind blows), the **strength of the wind,** and the **length of time the wind blows.** If all three factors are large, the waves will be large.



The size of wind waves is dependent on 3 factors, the length of time the wind blows, the strength of the wind, and the distance over which the wind blows (fetch).

Large storm waves can cause great damage. In fact, they are responsible for new inlets in many spots along the outer banks of North Carolina. We must remember that even normal waves can erode vast areas of shoreline. The white Cliffs of Dover, England, are an excellent example of how the constant action of normal waves can cut back the land.

The most spectacular kind of wave is the SEISMIC WAVE. These are commonly called "tidal waves," but that name is unfortunate. Seismic waves are the results of movements of the sea bottom or undersea landslides. In fact the word "seism" means earthquake in Greek. Since seismic waves have nothing what-so-ever to do with the tides, scientists have named seismic waves, TSUNAMI (pronounced su-nah'-mee). Tsunami is the Japanese word for seismic waves.

Although tsunamis are large at the coast, a ship at sea would hardly notice one passing. This is because their crests and troughs are so far apart. In shallower water the situation is completely different. The waves may become breakers as much as 100 feet high. On April 1, 1946, at Scotch Gap, Alaska, a tsunami completely demolished a radio tower that was placed on a rock 103 feet above the sea.

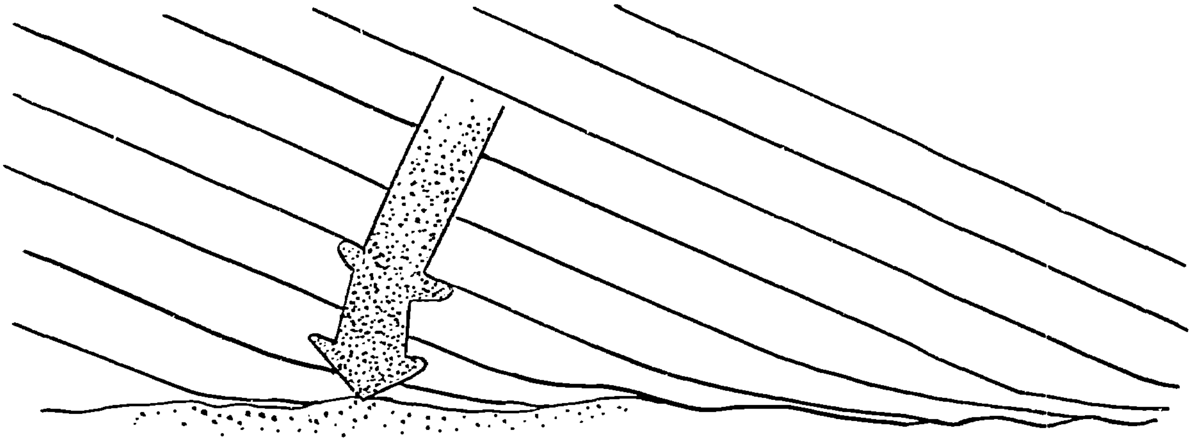
On the same day Dr. Francis P. Shepard witnessed the results of that disturbance in Hawaii. The wave took many lives and wrecked much property. Today there is a tidal wave warning system around the Pacific Ocean. When a seismograph station detects an earthquake, a warning is sent to all areas that could be hit by a tsunami.

WAVES AND BEACHES

If you live inland, you probably think the ocean beach is a never-changing spread of sand. But, this is far from what a beach is really like. The beach bordering an ocean is constantly changing. This is due to the force of the wind and waves. As we have already said, the energy of the wind is picked up by the waves far at sea. When these waves travel to a beach all this energy is released on the beach. The larger the wave, the more energy it releases.

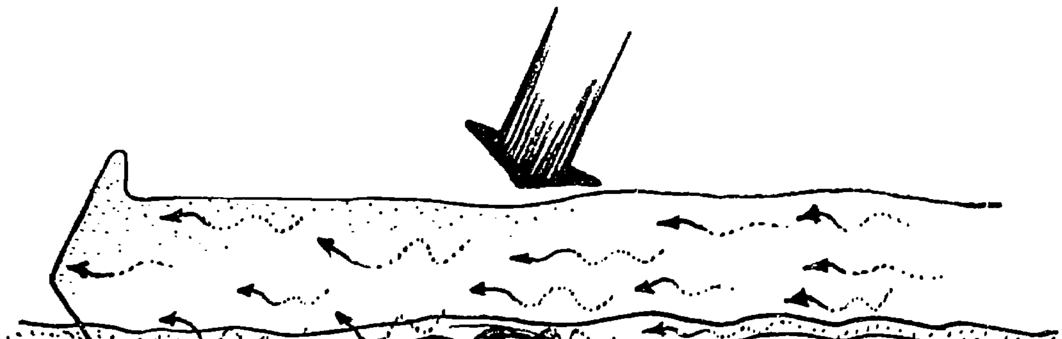
Although waves appear to hit the beach straight on, they seldom hit exactly parallel. Instead, they come from an angle. When a wave comes to a beach at an angle, the part closest to the beach feels bottom first. This part is then slowed down by friction with the bottom.

This allows the rest of the wave to "catch up". From the air, the wave would appear to be bent so that it would be parallel to the beach. This bending is referred to as REFRACTION. Refraction takes most of the angle with the shoreline out of a wave. But, there is usually a slight angle remaining.



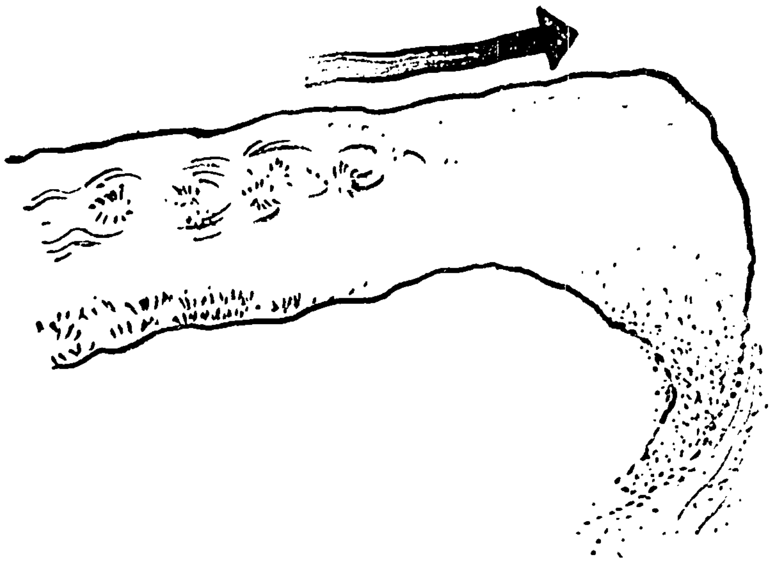
Waves approaching a beach at an angle will be refracted. As they approach the beach, the part of the wave near shore will feel bottom and slow down. The other part will continue to move as fast as always and will seem to catch up with the other part.

Since breakers are translation waves that carry water, many breakers hitting the beach at the same angle can transport large amounts of water along the beach. This movement of water along the beach is called the LONGSHORE CURRENT. The longshore current is only found in the breaker zone.



Waves hitting the shore at a slight angle cause a water current in the surf zone (translation wave zone) in the direction of the wave.

The longshore current is responsible for many of the natural alterations taking place on beaches. It can and does move tons of sand from one spot on the beach to another. For instance, next time you go to the beach notice the sand kicked up by incoming breakers. This sand kicked up from the bottom is moved along by the longshore current. The movement of sand along a beach is called the LITTORAL DRIFT or LONGSHORE TRANSPORT. The effects of the littoral drift can be seen on the ends of islands or peninsulas where the longshore current is operating. There, the waves no longer hit against the shoreline and the longshore current loses its energy. Sand is no longer carried along, but settles to the bottom. The results are long extensions of sand on the ends of these islands or peninsulas. We call these SPITS.



Island with a sand spit deposited on the end by the littoral drift.

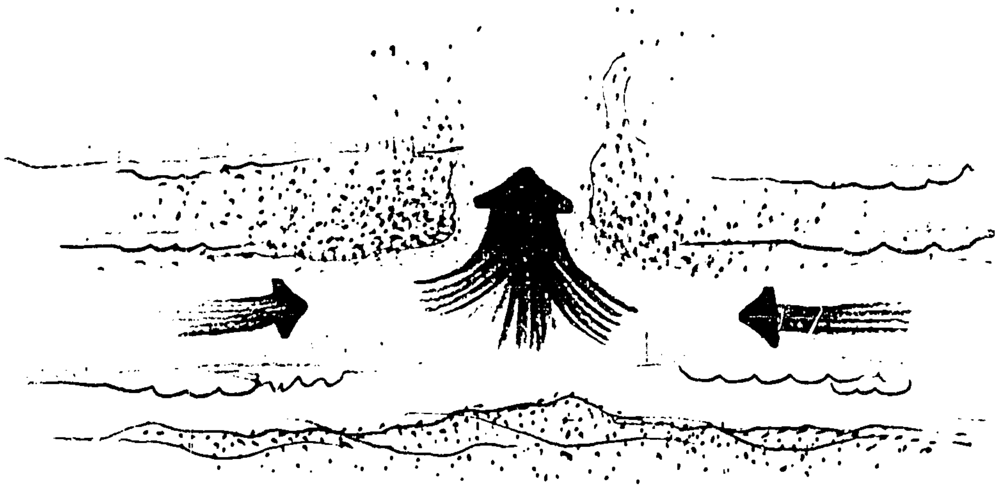
Another common movement of sand at the beach is a movement offshore and onshore. The results of this movement are long mounds of sand parallel to the beach called SAND BARS. Sand bars are usually present offshore after a week or two of high breakers. When the waves are small for long periods, the sand bar is pushed toward shore and spread out by the waves.

Associated with sand bars are RIP CURRENTS. Breaking waves carry large amounts of water over the sand bar. The force of many waves breaking over the bar keeps water trapped between the bar and the beach. If the bar is broken anywhere along its length, water will go back to the ocean through the hole. This water comes from both directions inside the bar and a current going straight away from the beach results. This is the rip current.

Rip currents are responsible for carrying many bathers "over their head" at the beach. Rips are strong and should be avoided. However, when necessary, surfers and lifeguards can use rips to get through the surf rapidly. Coming back through a rip is very difficult and should be attempted only if you are an excellent swimmer. If you are ever caught in a rip, swim parallel to shore. When you get out of the current, swim to shore. With just a little practice you can learn to spot rip currents. They usually hold back waves and are sometimes discolored by sand and other debris picked up from the bottom.

MAN'S CONTROL OF THE BEACH ENVIRONMENT

Years ago ocean engineers thought barriers were the best way to keep a beach from washing away. Lately, they have found that stabilizing a beach in one spot can cause trouble somewhere else along the beach. For instance, if we stopped the lottoral drift at the middle point on one of North Carolina's outer banks, the down current section of the beach would soon

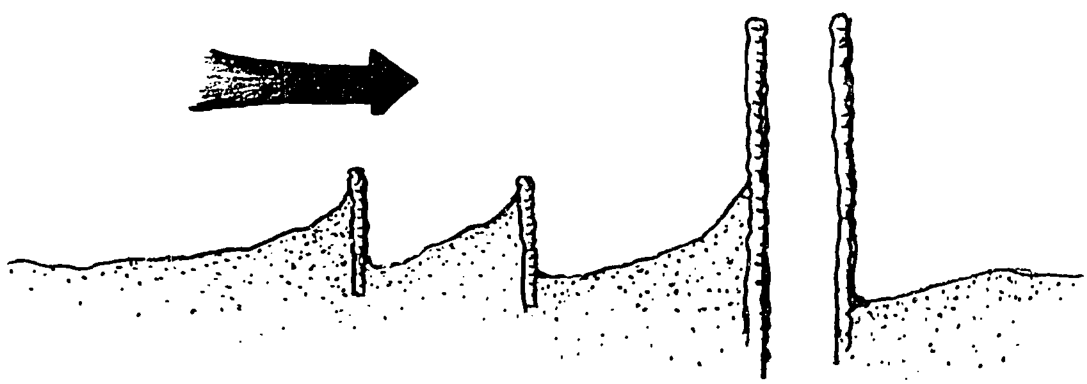


Water getting trapped between a sand bar and the beach can escape through a hole in the bar. This may produce a strong current running away from the beach. This current is called a rip current.

be deprived of its normal flow of sand. Eventually that section of the beach would erode away. The upcurrent section of the beach would erode away. The upcurrent section of the beach would become much wider because the barrier stops the sand here.

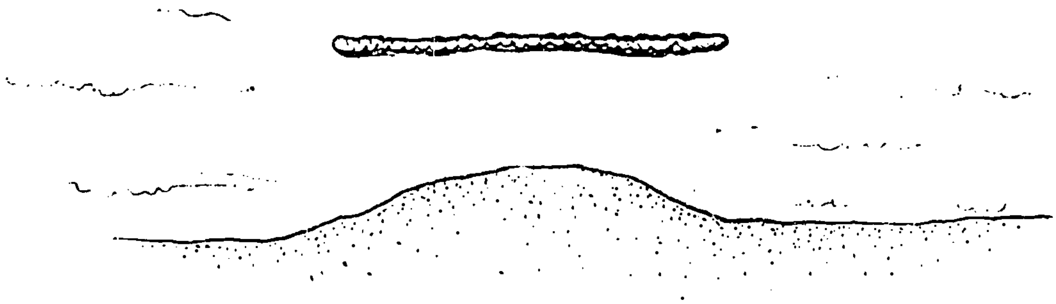
Many materials have been tried as barriers, but large rocks are the cheapest and easiest to obtain. These rocks are used to form JETTIES, GROINS, AND BREAKWATERS. Jetties are structures that extend into the ocean at the entrance of rivers or bays. They restrict the flow of water out of the river to a narrow channel. This tends to prevent SHOALS (sand mounds in rivers or lagoons) from accumulating at the river mouth.

Groins are similar to jetties but are usually placed perpendicular to the shore. They are grouped in a series, at critical points, to catch or hold sand.



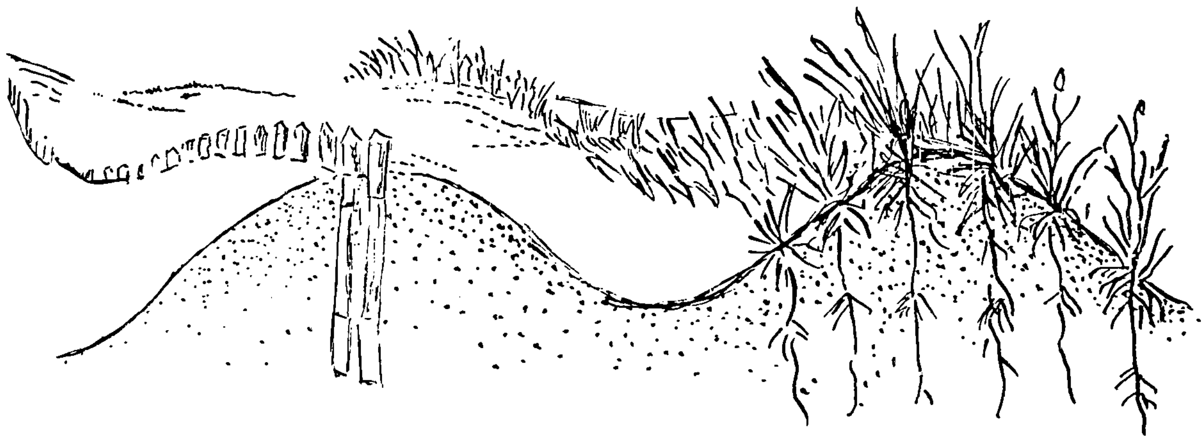
System of groins and jetties. The groins are perpendicular to the beach and used for catching and holding sand from the littoral drift. The jetties are found on each side of the mouth of the inlet or river. Its purpose is to keep sand from "shoaling up" in the entrance.

Breakwaters are used outside of a beach to break up the waves hitting shore. This creates a calm area for small boats to anchor. Although this sounds like a good idea, it does have some serious consequences. If the waves no longer strike the shore, the energy creating the longshore current is gone. When the longshore current encounters the calm water of the breakwater, the sand it carries is deposited. The water in the breakwater will then become increasingly more shallow. The beach on the down current side will continue to be eroded and will not receive sand from above. The beach there will become very narrow.



Breakwaters are built to slow down waves. This can make an excellent spot to anchor boats next to shore. Since they slow the waves down, sand is deposited behind them, ruining the beach.

In areas where shoals build up in a shipping lane, man has found a method to remove them. This is done by a boat, called a dredge, that is specially designed for the purpose. There are several kinds of dredges. One kind takes material off the bottom and transports it to spoils areas through long pipes. Another type dredge, called a hopper dredge, picks up the material and stores it in its hold until it can be carried offshore and dumped in the ocean.



Parallel dunes built by snow fence and grass. The snow fence, being nearly buried, will not stop much more sand. The vegetation has grown with its dune and will continue to build up. Notice also the stabilizing framework created by the root systems.

Above the water line on the beach, sand is moved by the wind. When the wind hits vegetation or some other barrier it slows down. The sand being carried by the wind then falls to the ground. If this continues for long periods, SAND DUNES are formed. Sand dunes are mounds of sand that pile up on the upper beach. They are very important in keeping storm waves from destroying the land behind them. Since the land along our coasts is valuable, man is now trying to preserve it by building sand dunes.

There are several methods man uses to build dunes. One method is to pile sand up with a machine. This is not the best way because the wind will soon blow it away. The best methods are the use of snow fences and beach grasses. With these methods, the wind actually builds the sand dune. The vegetation and sand fences will hold the dune in place.

Recent investigation has pointed out that vegetation is the ideal method to build dunes. In fact, until man came along this was the only way for dunes to become stable. Can you think of a reason why plants are the best dune builders? How about the holding power of the roots?

VOCABULARY

Bar: A mound of sand found offshore and parallel with the beach.

Beach: An area bordering an ocean that is affected by the waves.

Breaker: A wave in which the crest has fallen off.

Breakwater: A wave barrier placed offshore and parallel to the shoreline.

Crest: The uppermost part of a wave.

Groin: Barriers placed perpendicular to a shoreline.

Jetty: A barrier extending into the ocean at the mouth of a river or bay.

Littoral Dirft: The movement of sand along a beach because of the longshore current.

Longshore Current: Current of water that moves along a beach caused by waves breaking at an angle with shoreline.

Neutrally Buoyant Particle: A particle that neither floats or sinks because it has the same density as water.

Plunging Wave: A breaker in which the crest is thrown off into the trough ahead.

Rip Current: Water currents formed when water moves to sea through a break in an offshore bar.

Shoal: Shallow area caused by the deposition of sand or mud.

Spilling Wave: A breaker in which the crest slides down itself into the trough ahead.

Swell: A stable wave that does not carry water from one spot to another. The water particles in this wave move in a circle.

Trough: The low area of a wave between two crests.

Tsunami: A seismic wave that may reach great heights.

Wave Height: The vertical distance between a wave trough and a wave crest.

Wave Length: The horizontal distance between two crests.

Wave Period: The time that elapses between the passing of two wave crests.

QUESTIONS

Fill in the blanks with the correct answer.

1. The size of wind waves is dependent on __________________, ____________ ________ and ____________________.
2. ____________________ is the Japanese word for waves produced by seismic activity on the bottom of the ocean.
3. The time it takes for two wave crests to pass a spot is called the wave __________ __________.
4. Breakers carry water from one place to another and are called ____________________ waves by scientists.
5. Currents of water moving away from shore through a hole in the offshore bar are called ___________ __________ currents.
6. The ____________________ current is a current of water caused by breakers striking the beach at an angle.
7. The mass movement of sand along a coast because of the longshore current is called the ____________________.

DISCUSSION

1. Discuss why the littoral drift is important to the seaports of North Carolina.
2. Describe a method of measuring the height of waves. Make it your own invention or one you know about.
3. How are sand dunes formed and why are beach grasses important?

ACTIVITIES

Wind waves are produced by the friction of wind blowing across the water. Wind produced waves are the normal waves seen at the coast. Another type wave, seldom seen, is the seismic wave or tsunami. Tsunamis are produced by a disturbance on the bottom of the ocean.

Materials: shallow elongated pan, small fan (optional), sand, pencil, and paper.

Object: to create and observe, on a small scale, wind produced waves and seismic produced waves.

Methods: Wind Waves—Fill the pan with water about three-fourths full. Allow the water to settle. Use the fan or blow across the water in the pan. Observe the results.

Seismic Waves—Fill the pan about three-fourths full. Allow the water to settle down. Lift the edge of the pan slightly then allow it to fall back to the desk. Observe the results.

QUESTIONS:

1. What happened to our artificially produced waves when they got to the end of our pan? How does this differ from ocean waves striking a beach?
2. What differences do you notice about the size and number of waves produced by wind and seismic activities?
3. Waves will reflect if their energy is not expended. See if you can make the waves you produce expend their energy by placing sand shaped like a beach at one end of your pan. What happens to your waves now?

BEYOND THE LAND

Now that we have studied some of the processes at work along the edge of the sea, let's go beyond the shoreline. There are some important features in the oceans that should be familiar to us.

The relatively shallow area surrounding a continent is called the CONTINENTAL SHELF. The continental shelf extends from the beach to a point where a relatively steep-sloped drop-off to the deep ocean floor occurs. This slope is called the CONTINENTAL SLOPE.

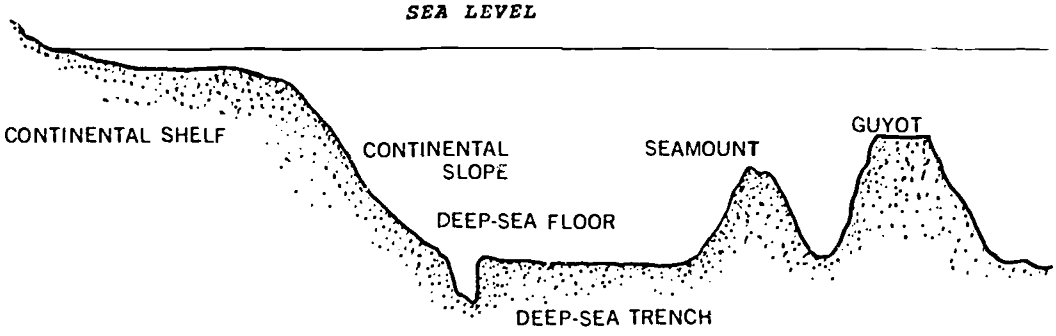
Continental shelves are very important to fishermen. Since they border continents, minerals washed from land mixes with the water over the shelf. Marine plants, mostly phytoplankton (phyto-plant, plankton-floating), are able to use these minerals to grow. The plants are then eaten by fishes and other important marine organisms.

The width of continental shelves differ from place to place. For instance, the continental shelf on the Atlantic Coast of North America is only about one mile wide at West Palm Beach, Florida. But at Beaufort, North Carolina, it is about forty five miles wide. The shelves may be made of many different types of material. They may be rocky, sandy, muddy or a combination of all three. They may also have depressions or hills on them. In fact, some hills stick out of the water as islands.

As we said, on the far edge of the continental shelf is the continental slope. The continental slope drops down to the deep ocean floor. For many years, scientists thought the deep ocean floor was a smooth featureless plain. With improved methods of sounding (testing the depth), they found that it is not a smooth plain. In fact, they found some of the most spectacular mountains and valleys anywhere on earth. The MID-ATLANTIC RIDGE is one of the mountain ranges found there. It extends north-south through the middle of the Atlantic Ocean and is connected to other ranges in other oceans. On each side of the Mid-Atlantic Ridge are DEEP SEA BASINS. These are simply deep depressions on the oceans floor. Also found on the deep ocean floor are isolated mountains called SEAMOUNTS. Some of these seamounts are flat topped and are called GUYOTS (pronounced jē yoos).

No one is sure how seamounts originated. Some oceanologists think they may be old volcanoes. But even if they are old volcanoes, how did some of the seamounts (guyots) get flat tops? They believe that millions of years ago, during the ice ages, these seamounts were above sea level. Above the water, they were eroded by wind and waves. When the many tons of ice over the continents melted, the level of the sea became much higher. This submerged the eroded tops of the seamounts. The hypothesis does not completely explain guyots, but it is a step in attempting to understand how they became flat-topped.

The deepest areas in the ocean are the deep sea trenches. The deepest trench known is the Mariana trench found in the Pacific Ocean. It has been measured at 35,700 feet, almost 7 miles deep. Trenches seem to be caused by volcano activity, but this has not been proven.



Profile of the Ocean Bottom.

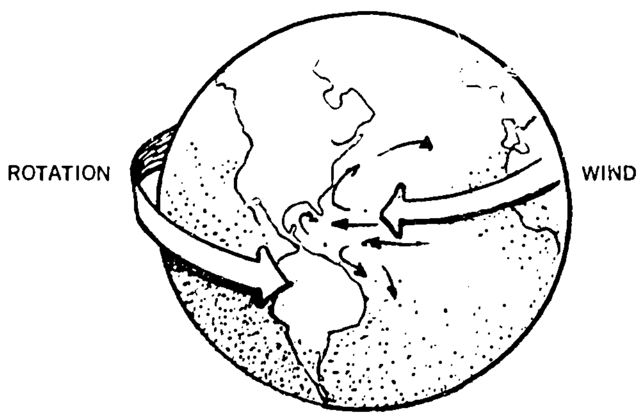
In all our studies so far, we have failed to consider the water in the sea. After all, this is what we think of when we think of the sea. Water is called the universal solvent by chemists, because it can dissolve so many substances. This is why sea water tastes salty to us. Scientists believe that millions of years ago, ocean water was not salty. With the erosion of land, minerals were dissolved by the streams, carried to the sea and concentrated by evaporation. Over millions of years, this gave the ocean its present salinity (this term refers to minerals dissolved in sea water). However, it should be remembered that most of the sea water is still water. Less than 4% is dissolved minerals and solids.

The most common elements (but not all of them) found dissolved in sea water are **chlorine, sodium, magnesium, potassium, calcium, iron,** and **carbon.** Two of the most common substances, chlorine and sodium, can combine to form common table salt, **NaCl.** During the Civil War sea water was boiled in large pots. When the water was completely evaporated, crystals of salt were left behind in the bottom of the pot.

These salt works were an early attempt at mining the sea. Today bromine is taken from sea water in large amounts. The cost is very high for removing most minerals from the sea. In fact, it costs more to mine most minerals from the sea than a company could make by selling them.

The ability of water to hold heat is very important to coastal dwellers. Land areas of the earth lose and gain heat very rapidly. The oceans are much slower. During the winter, coastal areas usually remain warmer than the inland areas. Often water at different depths will have different temperatures. Sometimes a very distinct line of difference can be found between the different temperatures. This line is called a THERMOCLINE.

The waters of the ocean are always in motion. **Trade winds and the spinning of the earth** are responsible for most of this movement. The most spectacular of the movements are called OCEAN CURRENTS. Ocean currents are caused by winds and the earths rotation. If we took a pan of water and suddenly moved it forward, we could see how the water would spill over the back of the pan. This is very similar to the way the water behaves in relation to the spinning of the earth. If there were no land masses to stop the water, there would be a continuous current from east to west in the sea. But, land masses prevent the ocean waters from doing this. Instead, currents turn away when they encounter a land mass.



Ocean currents are the results of two main factors. The earths rotation and the trade winds. The trade winds tend to push water along with them. The earths rotation has a different effect. The water tends to remain in place as the earth turns. Just as if the water was a separate shell and did not turn. This is seen by us as a current that is turned as it encounters land.

Direction of major ocean currents of the world. Notice the direction and extent of the Gulf Stream that occurs along the Eastern Coast of the United States.

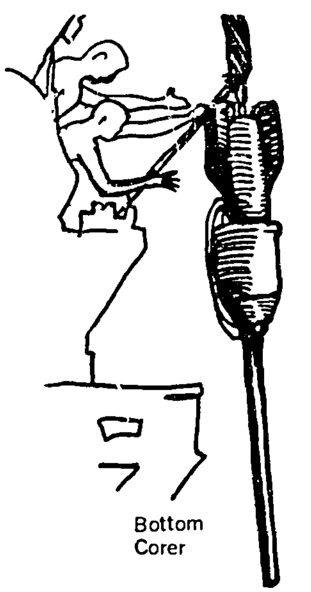
Ocean currents occur over all oceans, but the most studied of the ocean currents is the Gulf Stream. The Gulf Stream carries warm water from the Caribbean Sea to the east coast of the United States and the northwest coast of Europe. The warm waters of the Gulf Stream meeting the cold waters of the Labrador Current causes great fog clouds on the grand fishing banks of Newfoundland.

Another important current in the ocean is the UPWELLING CURRENT. This current is rather slow, but carries cold bottom water to the surface. This water may carry minerals from decayed animals that have sunk to the bottom. Phytoplankton can then use the minerals to grow.

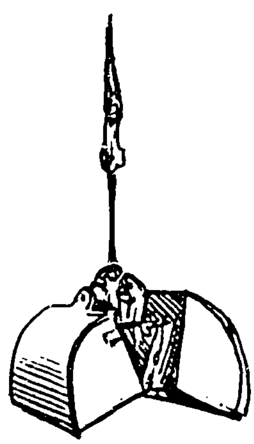
Oceanologists use many methods to study the ocean. One of his most important tools is the research vessel. These are specially designed ships that carry equipment for all phases of ocean study. This equipment must be designed to reach the great depths necessary to study the oceans properties. The pressure and temperatures are extreme at great depths.

Bottom studies are done by using coring devices. These are dropped from the ship and are attached by a cable. They are streamlined and very heavy. The speed and weight of the instrument help push a long pipe into the bottom material. The whole instrument is then brought to the surface and the material caught in the pipe is studied. By getting the material this way, the oceanologist can get a cross section of the sediments on the bottom. Another method of obtaining bottom materials is with the clam-jawed grabber. When this instrument touches the bottom, it closes, much like a clam, and a piece of the bottom is scooped up.

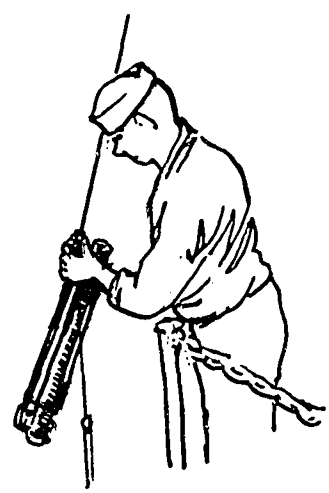
Salinity and temperature of deep water is tested by using the nansen bottle. These bottles are lowered to the desired depth on a cable, closed up, the temperature recorded, and the water is brought to the surface for study. Thermometers, pressure gauges, current meters, and cameras are also lowered into the ocean on cables.



Bottom Corer



Clam-jawed Grabber



Nansen Bottle

The fathometer is used to determine the depth of the ocean floor. This electronic instrument works by bouncing a sound wave, from the ship, off the bottom of the ocean. The longer

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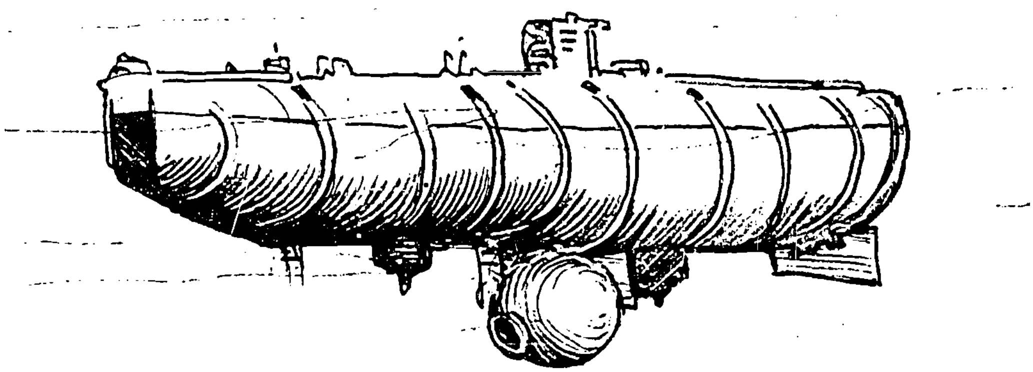
it takes the wave to reach the ship after bouncing from the bottom, the deeper is the water. Fishermen can use this device for finding fish. Sound waves pounce off the fish just as they do off the bottom. Fishermen then know where to drop their nets to catch a school of fish.

Oceanologists can also observe the bottom directly. If he only wants to go to 150 feet, he can safely use scuba gear (**S**elf-**C**ontained, **U**nderwater **B**reathing **A**pparatus). For deeper observation, the research submarines can dive to about 3,000 feet. The bathyscaph (from Greek meaning "deep boat") is designed for much deeper diving. The deepest dive was in the Challenger Deep, 35,700 feet. This was done by Jacques Piccard in his bathyscaph "Trieste." Piccard was able to prove that life exists at this great depth when he saw a fish swim by his window.



Bathyscaphe "Trieste", one of the first free "diving boats"

VOCABULARY

Continental Shelf: The area surrounding a continent, out to the steep-sloped drop-off to the deep ocean basin.

Continental Slope: The steep slope that marks the end of the continental shelf.

Deep Sea Basin: Flat bottom depression that forms the deep ocean floor.

Deep Sea Trenches: Trenches in the ocean floor believed to be caused by volcanic activity. They are the deepest spots in the ocean.

Guyots: Flat-topped seamounts.

Mid-Atlantic Ridge: Ridge of mountains in the Atlantic Ocean.

Ocean Currents: Water moving from one place to another in the open ocean due to winds and the earth rotation.

Phytoplankton: Floating plants in the sea, mostly microscopic.

Salinity: Amount of dissolved minerals in the sea.

Sea Mounts: Isolated mountains that are believed to be volcanos.

Thermocline: An area in the ocean where the temperature rapidly changes.

Updwelling Current: A current that moves from the bottom to the top of the oceans waters.

QUESTIONS

Fill in the blanks with the correct answer.

1. Water is called the ____________________ solvent because it dissolves so many substances.
2. The warm ocean current found off the coast of North Carolina is called the __________ __________ Stream.
3. The bathyscaph "Trieste" made its deepest dive to 35,700 feet in the __________ __________ Trench.
4. Microscopic floating plants in the sea are called ______________ ___.
5. Isolated flat-topped mountains in the sea are called ____________________.
6. The ____________________ ridge is a mountain range in the Atlantic Ocean.
7. The ____________________ corer is a device used to sample the oceans bottom.
8. The minerals dissolved in ocean water is called its ____________________.
9. The oceans water is ____________________ percent pure water.
10. The term Scuba stands for __________ ____________________ ______________ ___ __________ ______________ ______________.

DISCUSSION

1. Why are the continental shelf areas of importance to the fisherman?
2. Explain the hypothesis of why sea mounts have pointed tops and guyots have flat tops.
3. Write down a complete method of studying the continental shelf on the North Carolina coast. Include research ships and the instruments you would use.

ACTIVITIES

Sea water contains about four percent dissolved salts. If sea water is allowed to evaporate, a residue of salt will remain behind when the water is gone.

Materials: large beaker, sea water, bunsen burner, pencil and paper.

Methods: Place the sea water in the beaker. Evaporate the water out of the beaker by boiling it over the bunsen burner. Record the end results.

Questions:

1. What is the most abundant substance left behind?
2. How else may the salts be recovered besides boiling?
3. How did the great Salt Flats at Utah get there?